

A COLOR SEPARATING OPTICAL SCANNER HEAD

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ABSTRACT

A new design of a color separating optical scanner head is presented. Using optical fiber apertures combined with color separation filters, the light from a pixel is divided into its tri-color contents of magenta, yellow, and cyan. The mechanical design as well as the PIN-photodiode detector and amplifier electronic circuits are described in detail, and a few parameters of the detectors are given. Finally, some simple circuitry for additional analog processing, like edge enhancement and contour detection is suggested.

1 INTRODUCTION

1.1 Background

For several years an Ink Jet Color Plotter, developed at the Department of Electrical Measurements, Lund Institute of Technology, Lund, Sweden, Hertz et al. 1976, Bladh et al. 1979) has been used for the presentation of geodata and statistical information. Much of this data has been plotted on preprinted background maps in order to give a convenient interpretation of the plotted information. However, so far there is no simple way to introduce these background maps into the computer preparing the color plots, which has proven to be a bottleneck in some applications. This has led to the development of a color image drum scanner (Nilsson et al. 1981) which physically resembles the plotter but uses a new type of optical scanner head instead of the ink jet recording head. This color image scanner digitizes continuous-tone color images and converts them into a bilevel format compatible with the Color Jet Plotter.

This report describes in detail the principle as well as the mechanical and electrical layout of the optical scanner head used in the color image scanner.

1.2 The principle of a color scanner head

In principle, a color scanner head should consist of a light source to illuminate the image, a lens system, a color separation unit, and photoelectric devices that convert the detected color content into electrical analog signals.

In order to access individual picture elements, pixels, the photoelectric devices or the light source should be placed behind an aperture. The size of the aperture will determine the accessible pixel size, and therefore, the spatial resolution of the scanner head.

The color separation is normally achieved by expensive three-color prisms, which separate the original color picture into three separate pictures, each of which consists of one of the primary colors in the original picture only. A simplified version of this is shown in Figure 1.1, where colored optical filters are used outside the prisms

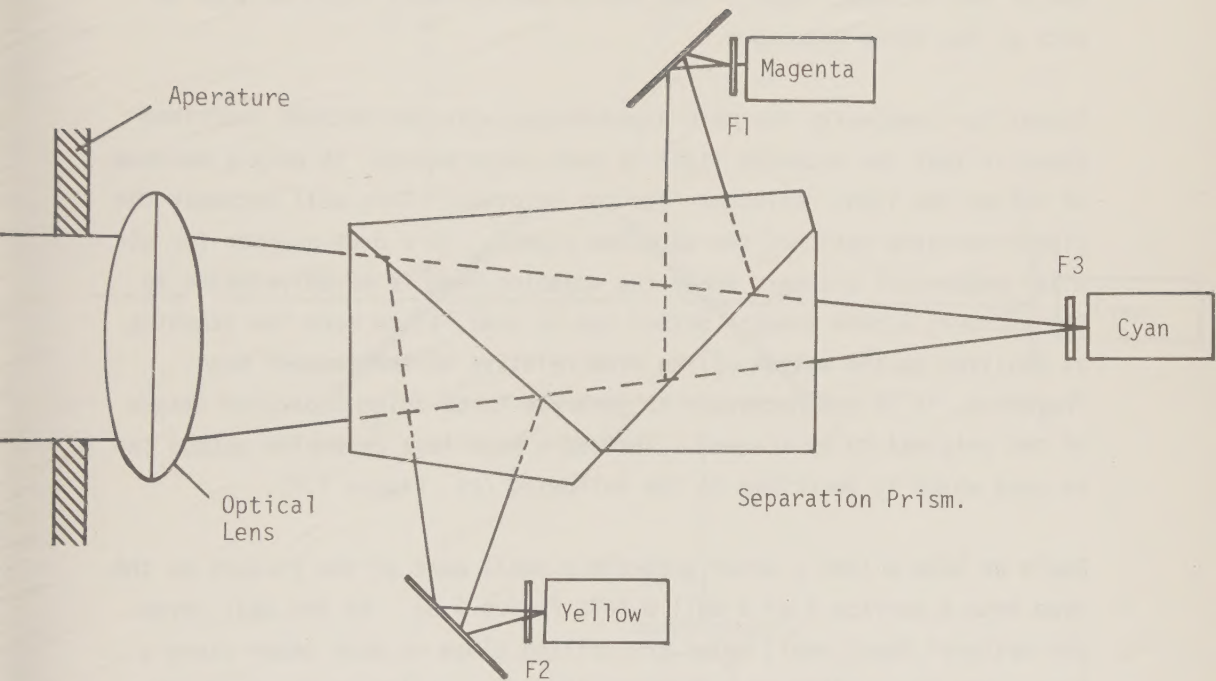


Figure 1.1. Color separation using a prism combined with three colored filters ($F_1 - F_3$) in front of the magenta, cyan, and yellow detectors.

instead of the colored prisms. The method is commonly used in TV-cameras where color-separated images of the original to be televised are required.

A variation of this method would be to combine the colored filters with two partly reflective mirrors, as shown in Figure 1.2. The first mirror (M_1) reflects 33% of the incident light while the other (M_2) reflects 50% of the incident light. Thus 33% of the incident light will go to each of the three detectors.

Except for complexity the main disadvantage with the methods described above is that the detected light in each color channel is only a maximum of 33% of the light reflected from the original. This will decrease the signal-to-noise ratio of the detected signal. In a drum scanner (or similar mechanical scanners where the scanning head is moved relative to the picture) a much simpler method can be used, since here the scanning is realized by the motion of the drum relative to the scanner head. Therefore, it is not necessary to generate three color-separated images of the original to be scanned. Instead a much less expensive method can be used which is described in the following (cf. Figure 1.3).

Again we have a lens L which projects a small part of the picture on the drum onto a surface S of a wall W (cf. Figure 1.3). In the wall three (or optional four) small holes are drilled close to each other along a line which is parallel to a scanning line (= parallel to the drum rotation). In each hole an optical fiber $O_1 - O_3$ is introduced which collects the light falling onto the finely ground end of the fiber and guides it through a color filter $F_1 - F_3$ onto a photoelectric device $D_1 - D_3$, e.g. a photodiode or a photomultiplier. Provided suitable filters are used the outputs of the devices $D_1 - D_3$ will represent the required color separation.

It is evident from Figure 1.3 that the three color signals generated in this way will be slightly out of phase, due to the fact that the apertures of the fibers are positioned on top of each other. However, this phase shift can easily be corrected for by delaying two of the signals compared to the third one by a suitable and constant time period. This

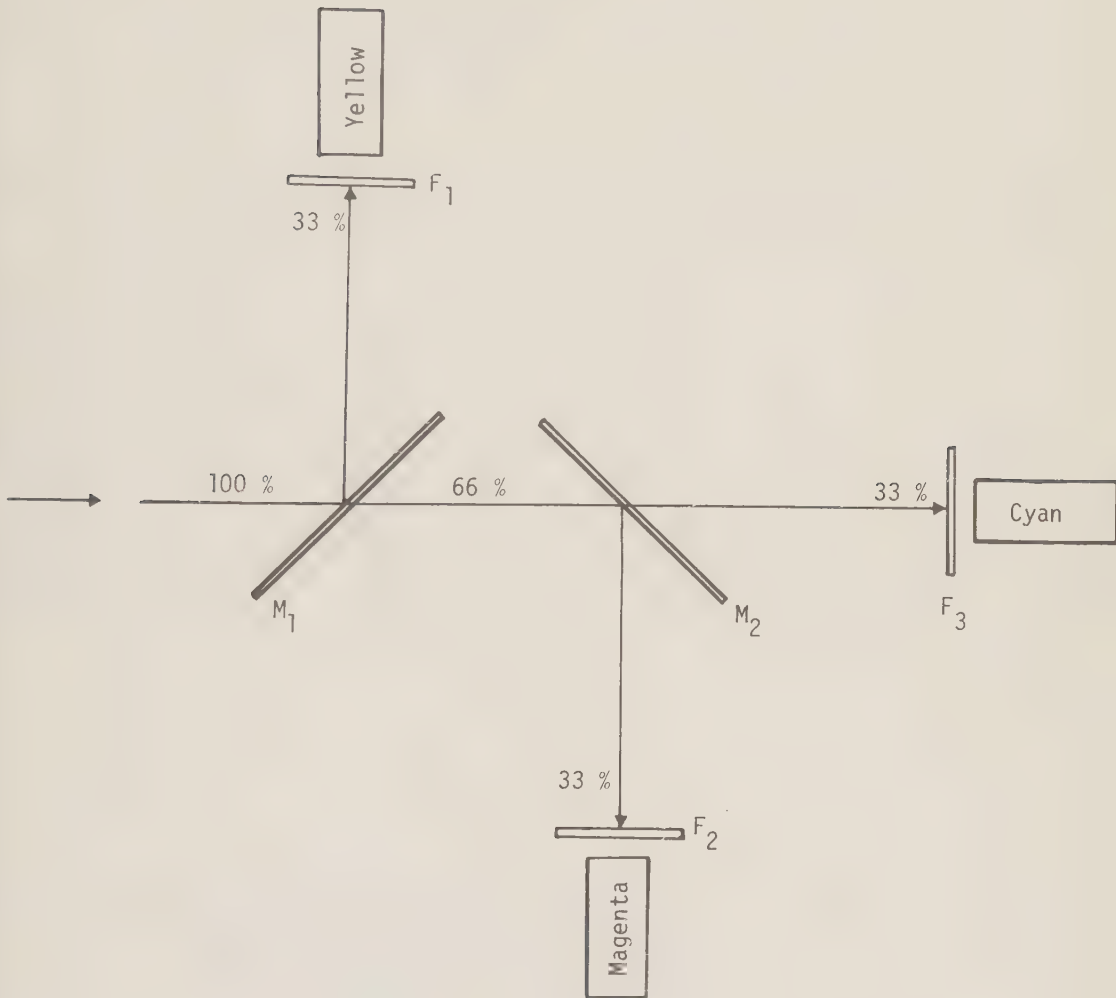


Figure 1.2. Color separation using two reflective mirrors. One mirror (M_1) reflects 33% of the incident light. The other mirror (M_2) reflects 50% of the incident light.

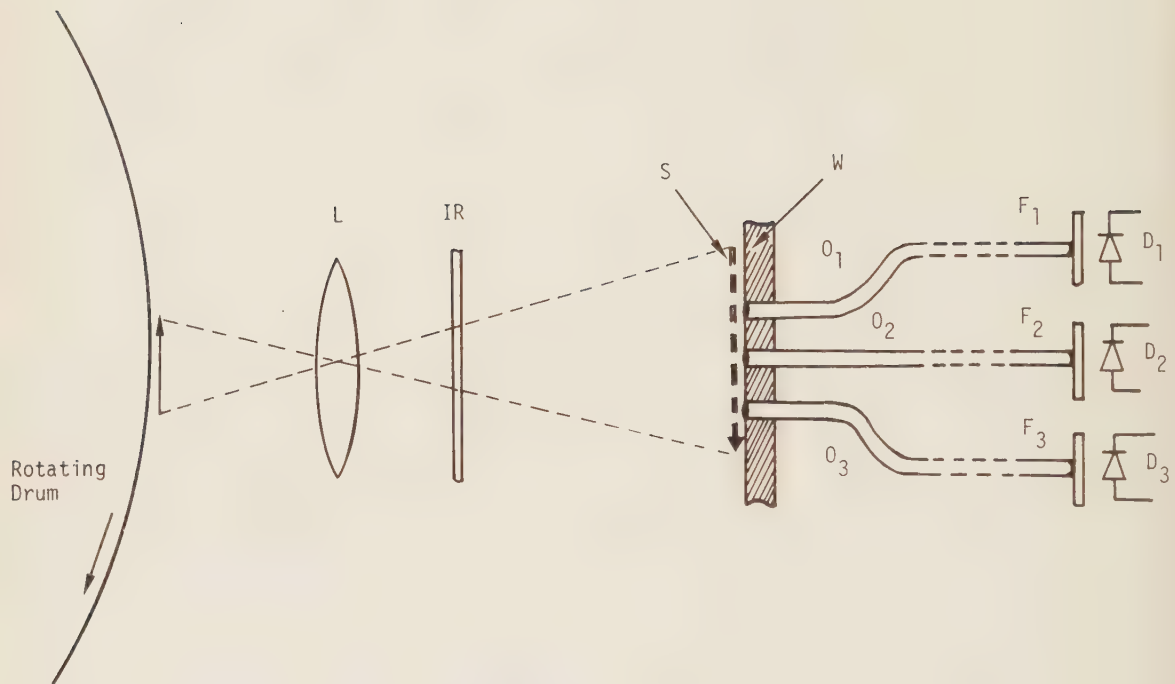


Figure 1.3. The lens L projects a small part of the image on the drum onto a surface S of the wall W. In the wall three small holes are drilled close to each other along a line which is parallel to a scanning line (= parallel to the drum surface movement). In each hole an optical fiber $O_1 - O_3$ is introduced which collects the light falling into its finely ground end and guides it through a color filter ($F_1 - F_3$) onto the photodetectors $D_1 - D_3$. The color separation filters in front of the photodetectors $D_1 - D_3$ separate the pixel color into its tri-color contents.

delay can be introduced either by an analog delay line or, after A/D-conversion of the three signals, by a digital delay line, e.g. a shift register. Since the phase shift between the signals depends on the drum speed of the scanner, the clock driving the analog delay line or the shift register should be controlled by the drum speed.

Besides its simplicity, the scanner head described in Figure 1.3. has another advantage: the optical fibers automatically determine the diameter of the scanning aperture. The optical magnification of the lens and the size of the optical fibers can be adjusted to achieve the desired scanning aperture.

2 A DETAILED DESCRIPTION OF THE SCANNER HEAD

2.1 General

The photograph in Figure 2.1 shows a prototype of the scanner head. It consists mainly of four elements: a light source, a lens system with an IR-filter, a color separation unit, and three photodiode detectors.

The physical size of the scanner head with a length of 150 mm and a width of 75 mm (including the lamp) is comparable to the Color Jet Plotter recording head (120 x 60 mm²).

2.2 The light source

To ensure that the detected light signal lies well above the noise level at the input of the first amplifier, the picture on the drum should be well illuminated at and around the pixels to be scanned. Also the lamp should illuminate the paper at a 45 degree angle as shown in Figure 2.1 to avoid the detection of surface reflections of the paper. In the scanner a halogen incandescent lamp (OSRAM 64255, 20W) with the spectral characteristics shown in Figure 2.2 was used. The lamp is delivered mounted in a cold-mirror reflector, having the form of a parabolic mirror. The parabolic reflector is used to concentrate the light from the lamp at the focus of the lens on the drum. The cold-mirror reflector also filters the light so that not too much heat radiation (IR-light) reaches the image on the drum (cf. Figure 2.3). If in addition to this an IR-filter is included in the lens system, almost no IR-light will reach the detectors. This is of special importance since photodiodes are used as detectors which normally have a high sensitivity to infra-red radiation.

2.3 Circuit for stabilization of lamp color temperature

As the spectral output from a tungsten lamp is strongly dependent on filament temperature, a simple circuit is used to stabilize the color temperature of the lamp (Figure 2.4). Here the light output from the lamp is stabilized by connecting the lamp filament as one resistive element in a Wheatstone bridge. Bridge balance, and therefore stable filament temperature, is obtained by a simple amplifier circuit controlling the current through the bridge.

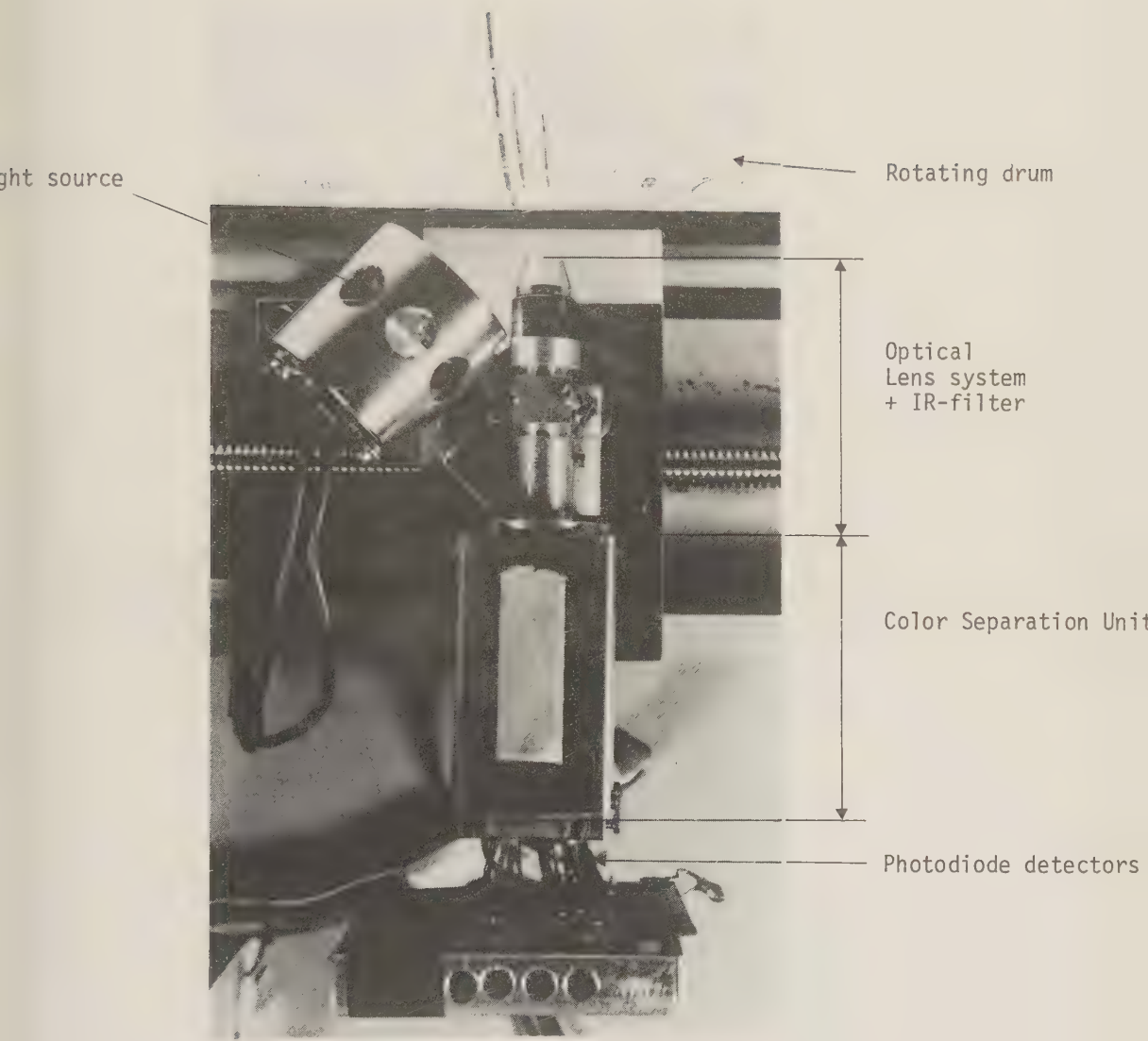


Figure 2.1. The prototype of the scanner head. It consists mainly of four elements: a light source, a lens system with an IR filter, a color separation unit, and three photodiode detectors.

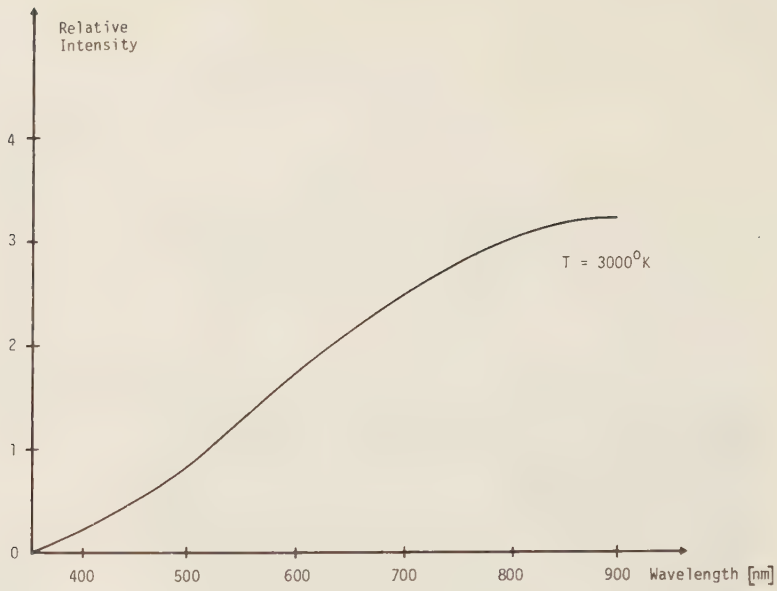


Figure 2.2. Spectral characteristics of the lamp (OSRAM 64255, 20W).

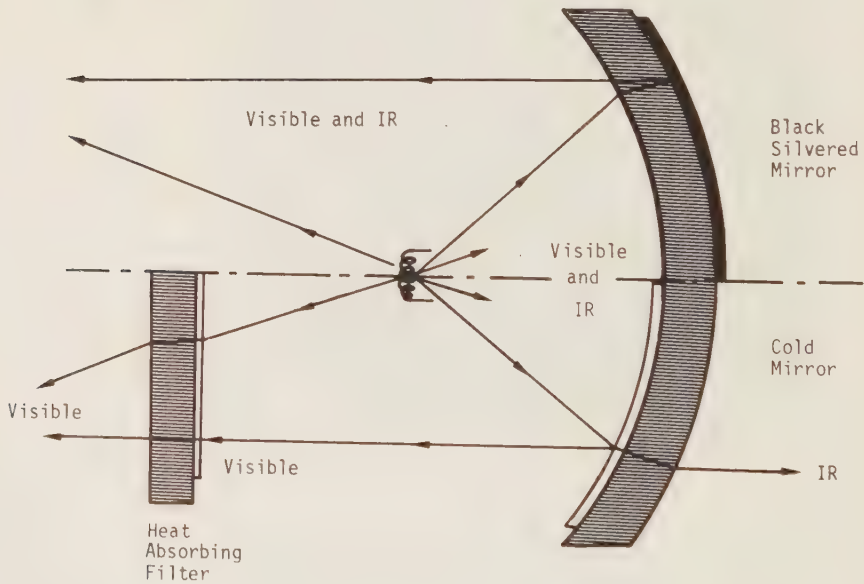


Figure 2.3 The function of the cold-mirror reflector in the lamp. The lower part of the figure depicts the effect of the extra IR-filter in the lens system.

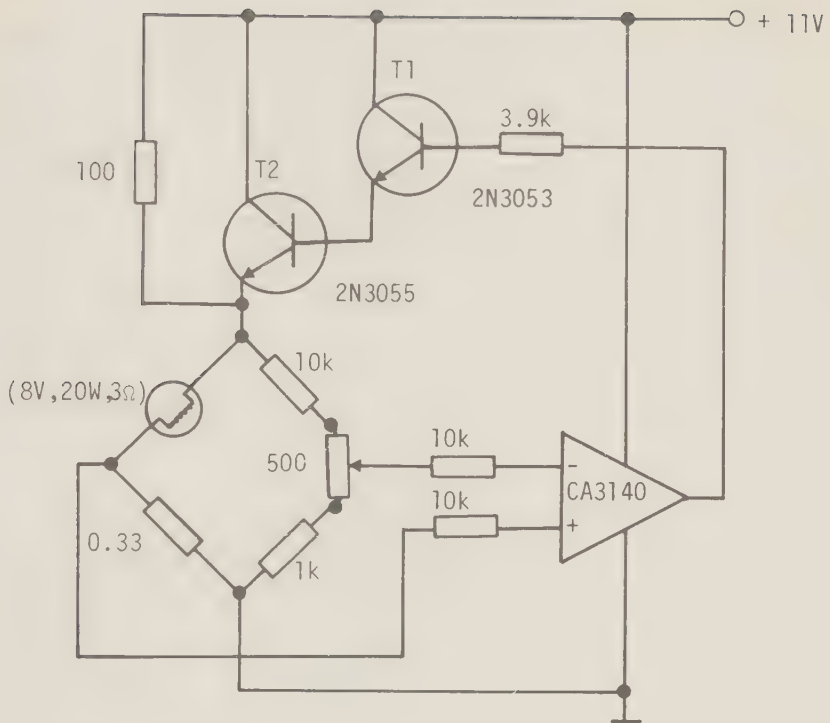


Figure 2.4. Electronic circuit used to stabilize the color temperature of the lamp.

The bridge circuit shown in Figure 2.4 makes use of the lamp's positive resistive temperature coefficient (Darlington, 1980). A potentiometer is used to set the desired color temperature. The difference amplifier (CA 3140) detects the bridge unbalance and controls the Darlington emitter follower Q_1 and Q_2 , and therefore, the current fed to the lamp filament, with negative feedback.

2.4 The optical assembly and color separation unit

The optical assembly consists of a 10x Zeiss microscope objective and an IR-filter (Zeiss BG-18) combined with a concave lens ($\phi = 6$ mm and radius = 5 mm). The normal focusing distance is 12 mm from the front lens of the objective to the drum surface. At this distance the lenses provide a 4x optical magnification of a pixel, on the aperture of the optical fibers (cf. Figure 2.5). Each optical fiber (ASEA, OC 1 x 400-L) has a core diameter of 0.4 mm. When the fiber ends are used as scanning apertures in the scanner head, they will therefore correspond to a pixel size of $0.4\text{mm}/4 = 0.1$ mm in the image or the drum.

The optical fiber apertures are arranged as shown in Figure 2.6. As each optic fiber has a core diameter of 0.4 mm which represents the aperture, the distance between the apertures has to be a multiple of 0.4 mm. To achieve this the outer diameter of the fiber has been stripped to 0.6 mm. This was achieved by keeping only the optic fiber core surrounded by the cladding and primary sheath, thus decreasing the outer dimensions from 3 mm to 0.6 mm in diameter. The small outer diameter allowed a distance of 0.8 mm between the center of each aperture. Thus the phase shift mentioned earlier between the three channels will be 0, 2, and 4 pixels starting from the top in Figure 2.6. This is corrected for in the scanner head analog circuitry, because it is much easier to perform the correction after the A/D-conversion, using digital shift registers.

The color separation filters are positioned at the other end of the optic fibers as shown in Figure 2.7. The optic fiber end is centered in a large hole ($\phi = 10$ mm) which serves as a combined filter and de-

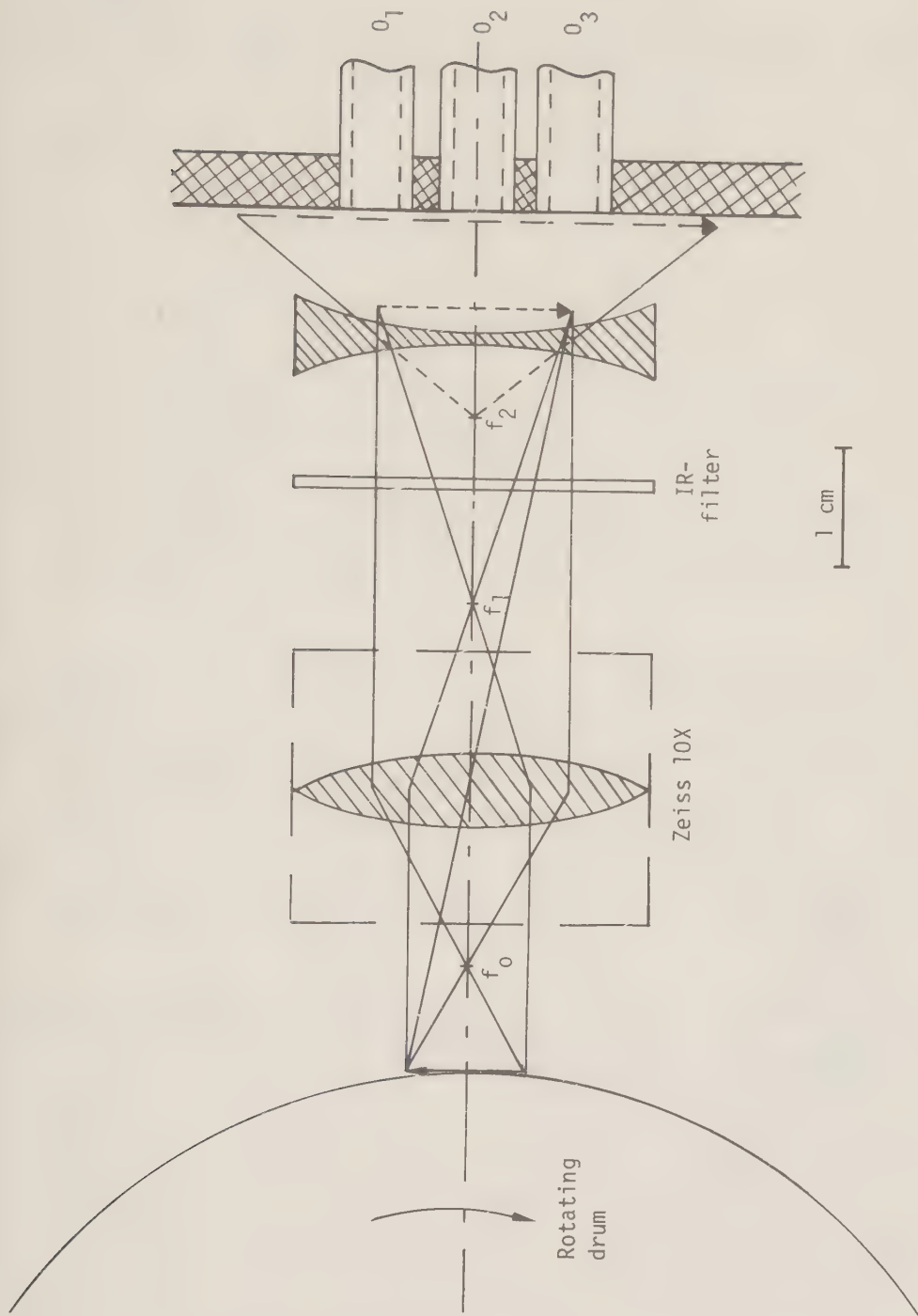


Figure 2.5. Optical assembly and color separation unit. The lenses provide a 4x optical magnification of a pixel at the apertures of the optical fibers ($O_1 - O_3$).

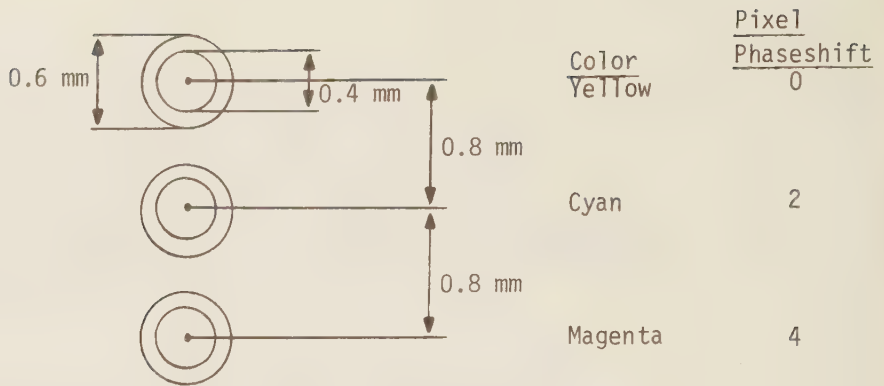
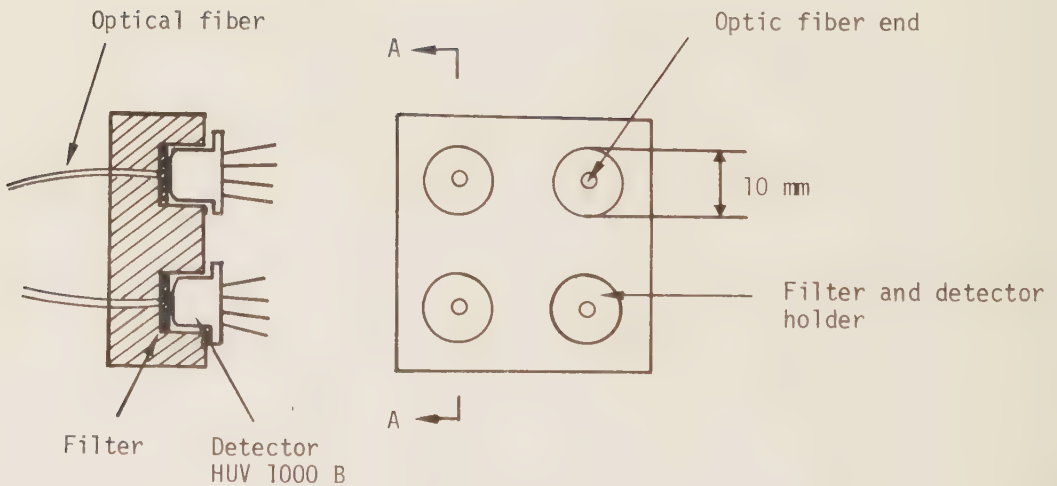


Figure 2.6. Optical fiber arrangement in the color separation unit. Each fiber has a core diameter of 0.4 mm and an outer diameter of 0.6 mm. The distance between the centers of the fiber apertures is 0.8 ($= 2 \times 0.4$). The color that is separated is shown to the right, as well as the introduced pixel phase shifts.



Section A-A

Figure 2.7. The optic fiber ends are centered in a circular hole ($\phi = 10$ mm) which serves as a combined color separation filter and detector holder. The figure shows four such holders. Normally only three of them are used. The fourth is optional (see section 4.4).

tector holder. Any combination of color separation filters can be used. However, the scanner head normally uses KODAK Wratten filters K25 (red), K47 (blue), and K58 (green) for the detection of cyan, yellow, and magenta signals, necessary for the control of the respective ink jets in an ink jet plotter (Nilsson and Nygren 1981). The spectral transmission curves of these filters are shown in Figure 2.8.

2.5 The detector electronic circuitry

All three color channels use a similar electronic detector circuitry for the amplification, gain and input balance control. Thus, only the electronic circuitry of one channel will be described below.

Figure 2.9 shows the circuit diagram of the detector/amplifier combination, HUV-1000B. The same figure contains the additional amplifiers that are necessary to provide a $\pm 5V$ input signal to the A/D-converter.

The photodiode is used with zero bias in a photovoltaic mode of operation. In this mode there is no dark current, making it ideal for low measurements. As demonstrated in the general current-voltage characteristics of a photodiode (cf. Figure 2.10) photovoltaic operation can either be linear or logarithmic depending on the value of the load resistance. If the load resistance is very high ($>10^{11}\Omega$) the logarithmic mode is obtained. This approximates an open circuit operation mode and corresponds to a horizontal load line in Figure 2.10.

Linear operation is obtained if the load resistance is low, which approximates a short circuit operation mode. The corresponding load line is also shown in Figure 2.10. In the HUV-1000B the detector/amplifier combination is connected for a linear photovoltaic operation. The transimpedance amplifier provides the low load resistance necessary for such an operation. The negative input terminal of the amplifier is at virtual ground. Therefore, the dynamic resistance seen by the photodiode is R_f/A (where R_f is the feedback resistance and A is the loop gain) which is typically less than 10 ohms. The value actually varies with frequency as

$$Z = \frac{R_f}{A(1 + (2\pi\nu R_f C_f)^2)^{1/2}}$$

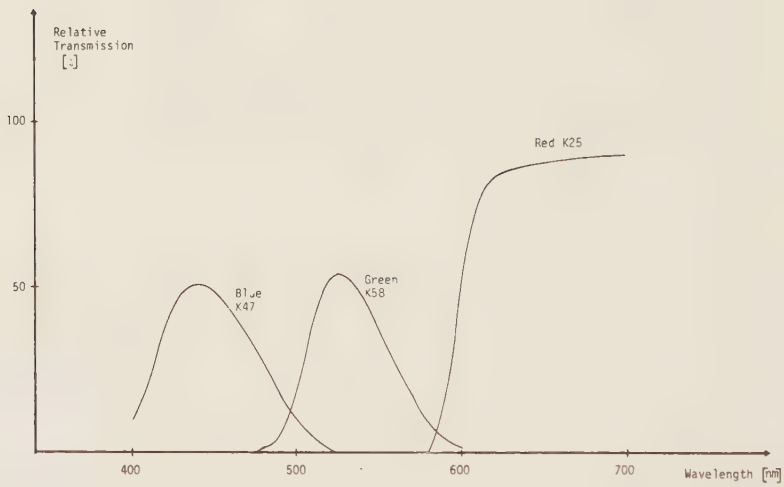


Figure 2.8. The spectral transmission curves for the color separation filters (Kodak Wratten filters).

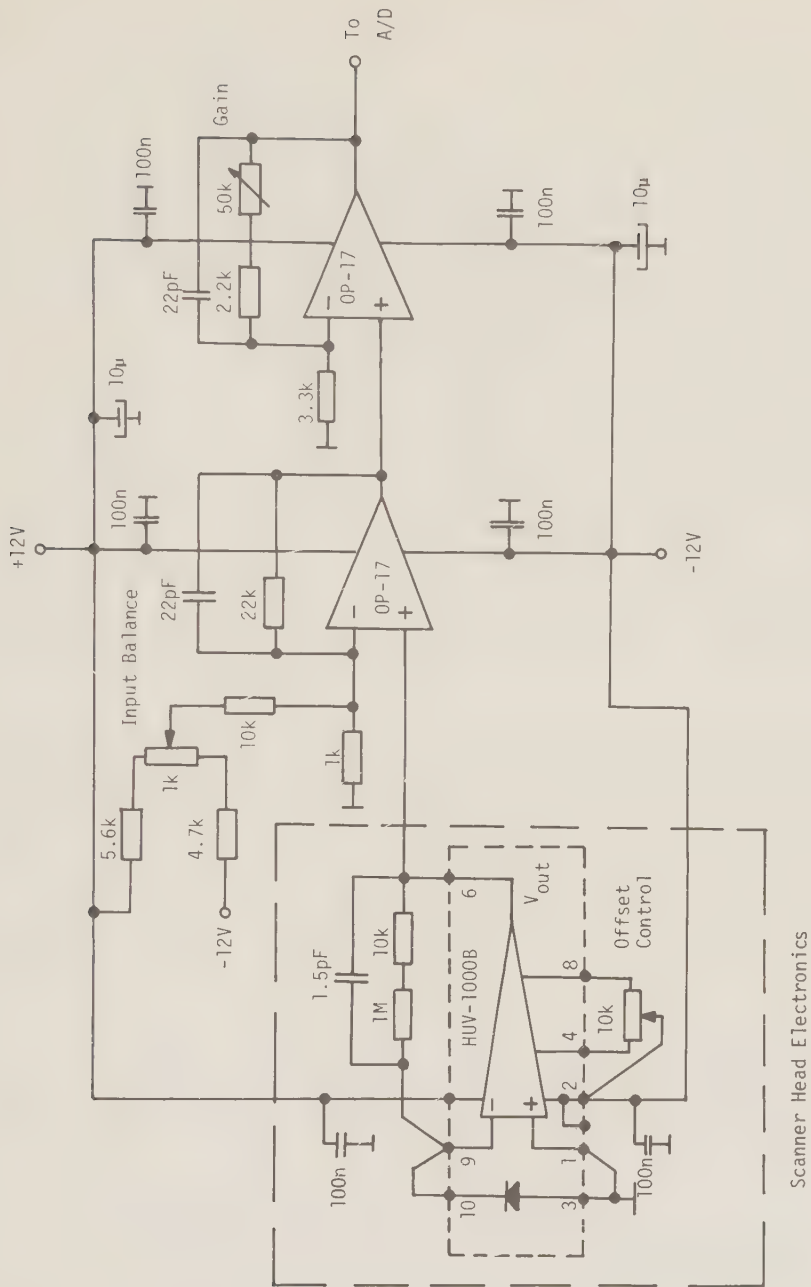


Figure 2.9. Circuit diagram for the detector/amplifier and additional amplifiers. (One channel only).

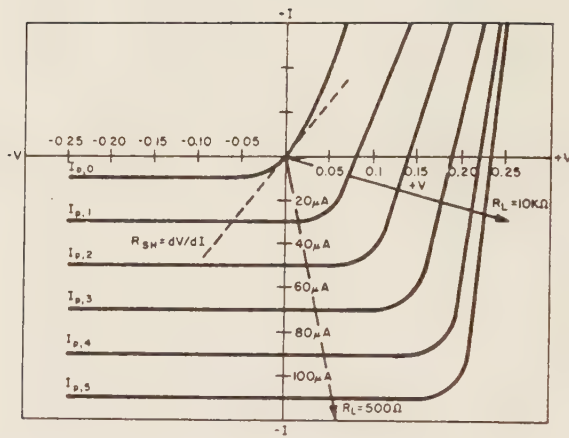


Figure 2.10. General current-voltage characteristics of a photodiode.

where Z is load impedance

ν is the frequency

and C_f is the feedback capacitance.

This low load resistance also optimizes the response time because the internal capacitance of the photodiode is shorted out. Instead the response time will be limited by the time constant of R_f with its own capacitance in parallel with the 1.5 pF shown in the circuit diagram.

Another advantage with this circuit is that the thermal noise contributions to the input stage come mainly from R_f . Thus, if R_f and A are sufficiently large, this amplifier design will attain high closed loop gain with no signal integration and minimal thermal noise.

A more detailed theoretical analysis of the noise characteristics for such a photodiode/amplifier configuration can be found in Netzer (1980) and EE&G Application Note D3011 (1975).

The HUV-1000B photodiode/amplifier is using an external feedback resistance R_f of 1.1 M Ω . This results in a current transfer ratio of $1.1 \cdot 10^6$. The 1.5 pF capacitance in parallel with the feedback resistance is used to limit the signal bandwidth. It gives the amplifier a single pole rolloff at $f = 1/(2\pi R_f C) = 96.5$ kHz and thus reduces the noise at higher frequencies.

The first of the two following amplifiers (PMI OP-17) provides offset balance thus allowing the DC-level of the signal to be varied. The voltage gain at this stage is approximately a factor of 23.

The final amplifier provides gain control to adjust the output signal to the input requirements of the A/D-converter. The voltage gain of this stage can be varied between a factor of 1.7 to 17. In this way the dynamic range of the output signal can be adjusted to ± 5 V necessary to drive the A/D-converter, where +5V represents maximum white in the image and -5V represents maximum black.

3 PROPERTIES OF THE SCANNER HEAD DETECTORS

3.1 General data

The parameters for the photodiode and the photodiode/amplifier combination that are given by the manufacturer are summarized in Table 3.1. A few additional calculated or measured parameters are presented in the following sections.

Photodiode/amplifier parameters (HUV-1000B)

Active area	5.1	mm
Spectral range	200-1150	nm
Responsivity at 950 nm	12	10^7 volts/watt; $R_f = 200 \text{ M}\Omega$
Noise Equivalent Power	0.87	$\cdot 10^{-13}$ watts/Hz $^{1/2}$ for $\lambda = 900 \text{ nm}$, $f = 20 \text{ Hz}$ and $B = 1 \text{ Hz}$
Frequency range	DC-1	MHz, $R_f = 10 \text{ kHz}$
Open loop gain	$2 \cdot 10^5$	
Output resistance	80	Ω
Slew rate	6	V/ μ s
Photodiode capacitance	150	pF
Photodiode shunt resistance	>100	M Ω

Table 3.1. Photodiode/amplifier data given by the manufacturer.
(EG&G, data sheet D3002B-2)

3.2 Quantum efficiency and responsivity

The spectral response of a photodiode can be stated as quantum efficiency, Q_E (electrons/photon) or responsivity R (ampere/watt) as a function of wavelength. The relation between the two is given by

$$R = \frac{\lambda \cdot Q_E}{1240} = \frac{I_p}{\phi} \quad [\text{ampere/watt}] \quad (1)$$

where λ is wavelength in nm,

the value 1240 is the product of Planck's constant and speed of light,

I_p is photocurrent in amperes

and ϕ is radiant flux in watts.

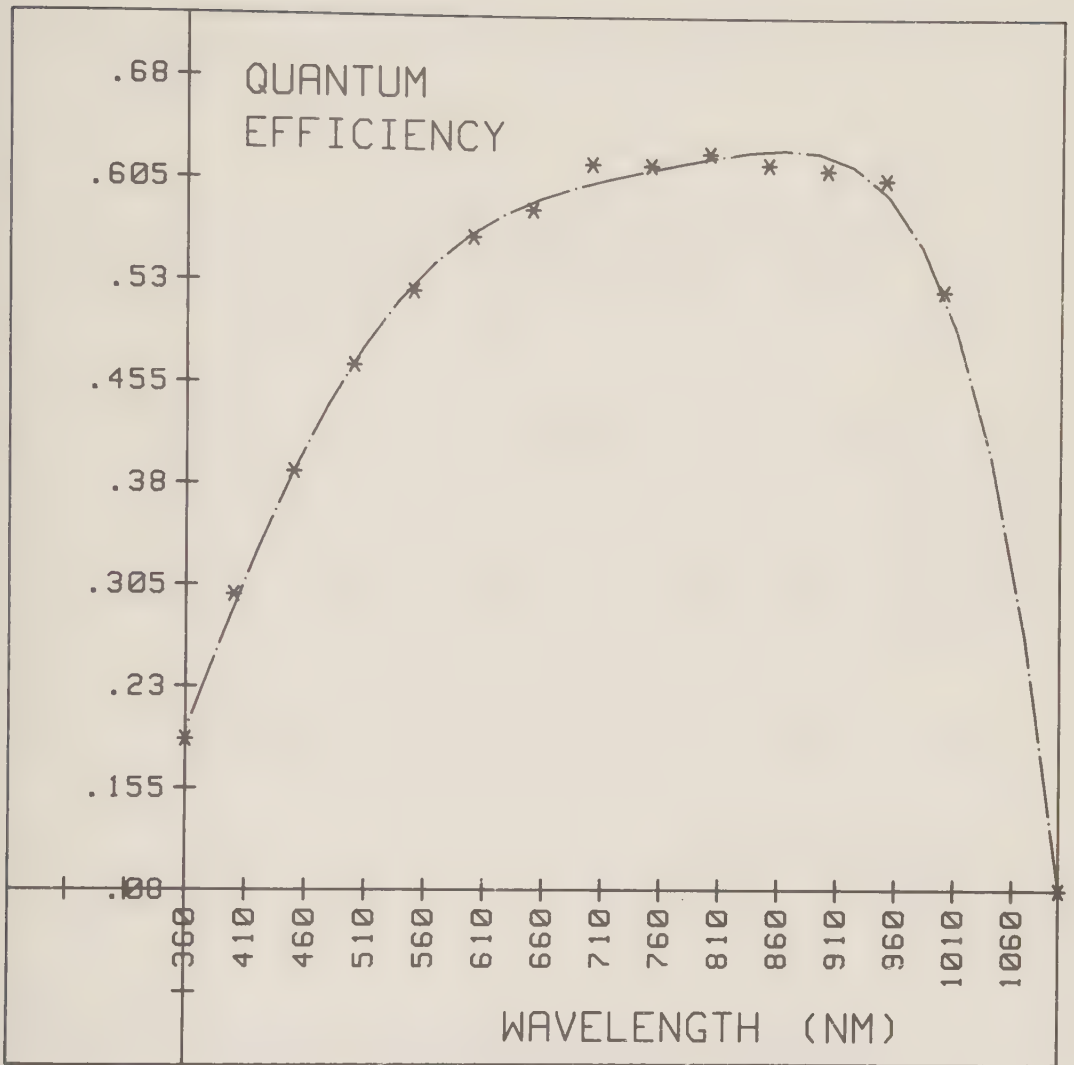


Figure 3.1. Spectral response of the photodiode detector showing quantum efficiency (electrons/photon) as a function of wavelength (nm).

The measured quantum efficiency of the photodiode in the scanner head is shown in Figure 3.1, which depicts the enhanced response in the blue region of the spectrum for which the diode was selected.

3.3 Linearity

The PIN photodiode behaves like a constant current generator. The amount of current is proportional to the incident light intensity. Any variation in responsivity with light intensity represents a variation in linearity.

Application Note D3011 (EG&G) contains a formula for the calculation of the linearity error for a given load resistance. Also, a formula to calculate the total responsivity of the photodiode/amplifier combination is given. It is a product of the wavelength dependent photodiode responsivity in amperes/watt and the frequency dependent transimpedance (Z_T) of the closed-loop amplifier, where Z_T is given as

$$Z_T = \frac{1}{\left| \frac{1}{R_f} + \frac{1}{A} \left(\frac{1}{R_f} + \frac{1}{R_{SH}} \right) \right|^2 + (2\pi\nu)^2 \left(C_f + \frac{C_f + C_j}{A} \right)^2}^{1/2} \quad (2)$$

where Z_T = transimpedance

R_f = feedback resistance

C_f = feedback capacitance

R_{SH} = photodiode shunt resistance

C_j = photodiode capacitance

ν = frequency

A = loop gain

With $R_f = 1.1 \text{ M}\Omega$, $C_f = 1.5 \text{ pF}$, $A = 10^6$ (at DC), $R_{SH} = 100 \text{ M}\Omega$ and $C_j = 150 \text{ pF}$ the normalized responsivity can be calculated, and yields the result shown in Figure 3.2.

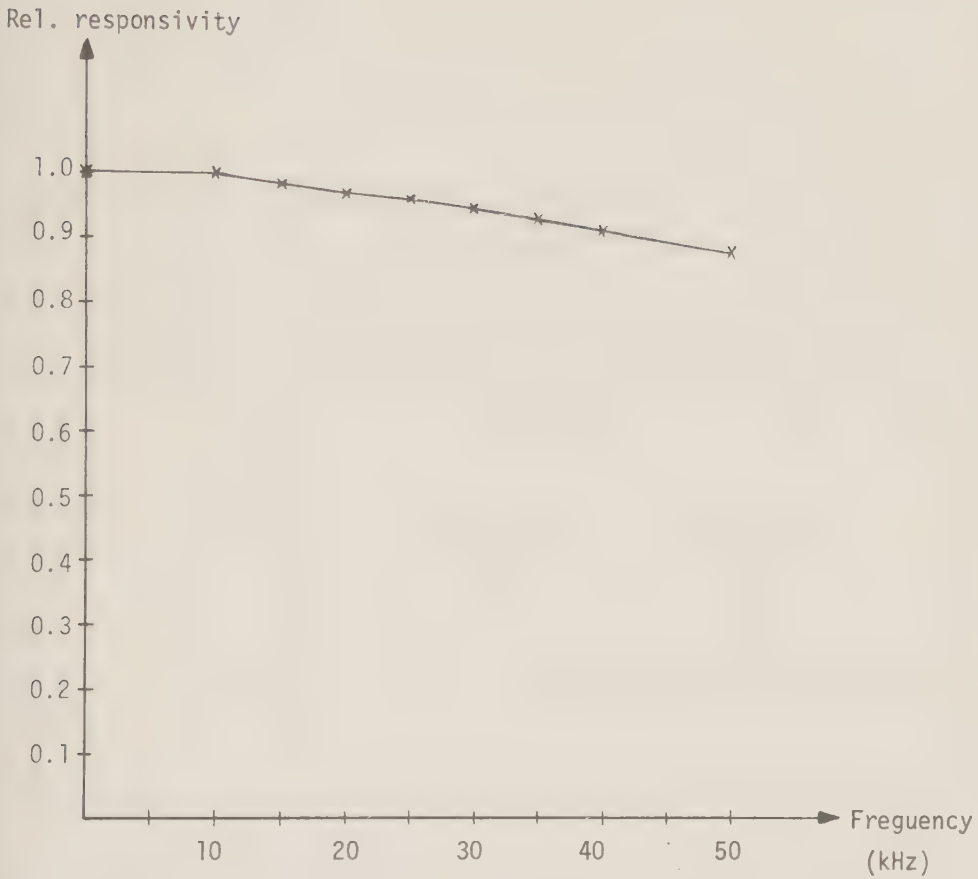


Figure 3.2. Relative responsivity as a function of signal frequency in kHz. The result is calculated using equation 2 with $R_f = 1.1 \text{ M}\Omega$, $C_f = 1.5 \text{ pF}$, $A = 10^6$, $R_{SH} = 100 \text{ M}\Omega$ and $C_j = 150 \text{ pF}$.

3.4 Signal/Noise ratio

The signal/noise ratio was measured at the output of the final amplifier, shown in Figure 2.9, in each of the three color channels. During the measurement the Kodak Wratten filters K25, K48, and K58, were used in the cyan, yellow, and magenta channels, respectively.

The noise voltage was measured at two different situations: At maximum incident light (maximum detected white) and with no incident light (maximum black). No significant difference between the two situations could be registered. The measured noise levels are presented in Table 3.2. The signal to noise ratios were calculated knowing that the maximum dynamic range of the analog signal was $\pm 5V$.

Color channel	V_{p-p} [mV]	S/N [dB]
Magenta	180	35
Cyan	200	34
Yellow	250	32

Table 3.2. Noise levels in the three color channels

3.5 Frequency characteristics

The transfer characteristics of the photodiode and the following amplifiers was measured using pulses from a red light emitting diode (LED). The LED (FLV 101) was pulsed from a pulse generator to simulate reflected light pulses from small white details in an otherwise black image. The result, shown in Figure 3.3 yielded a -3dB point at 28 kHz.

For comparison, consider the maximum drum surface speed of 5 m/s. At this speed the drum surface moves 0.1 mm in 20 μs , i.e. one pixel in the image, which requires a cut off frequency of at least 25 kHz. In the image scanner (Nilsson and Nygren 1981) two such pixels are sampled and weighted to yield an 0.2 mm pixel value. Thus, at maximum drum speed (5 m/s) the image is sampled twice during an interval of 40 μs . Normally, however, a drum surface speed of 3.5 m/s is used, increasing that time interval to approximately 60 μs .

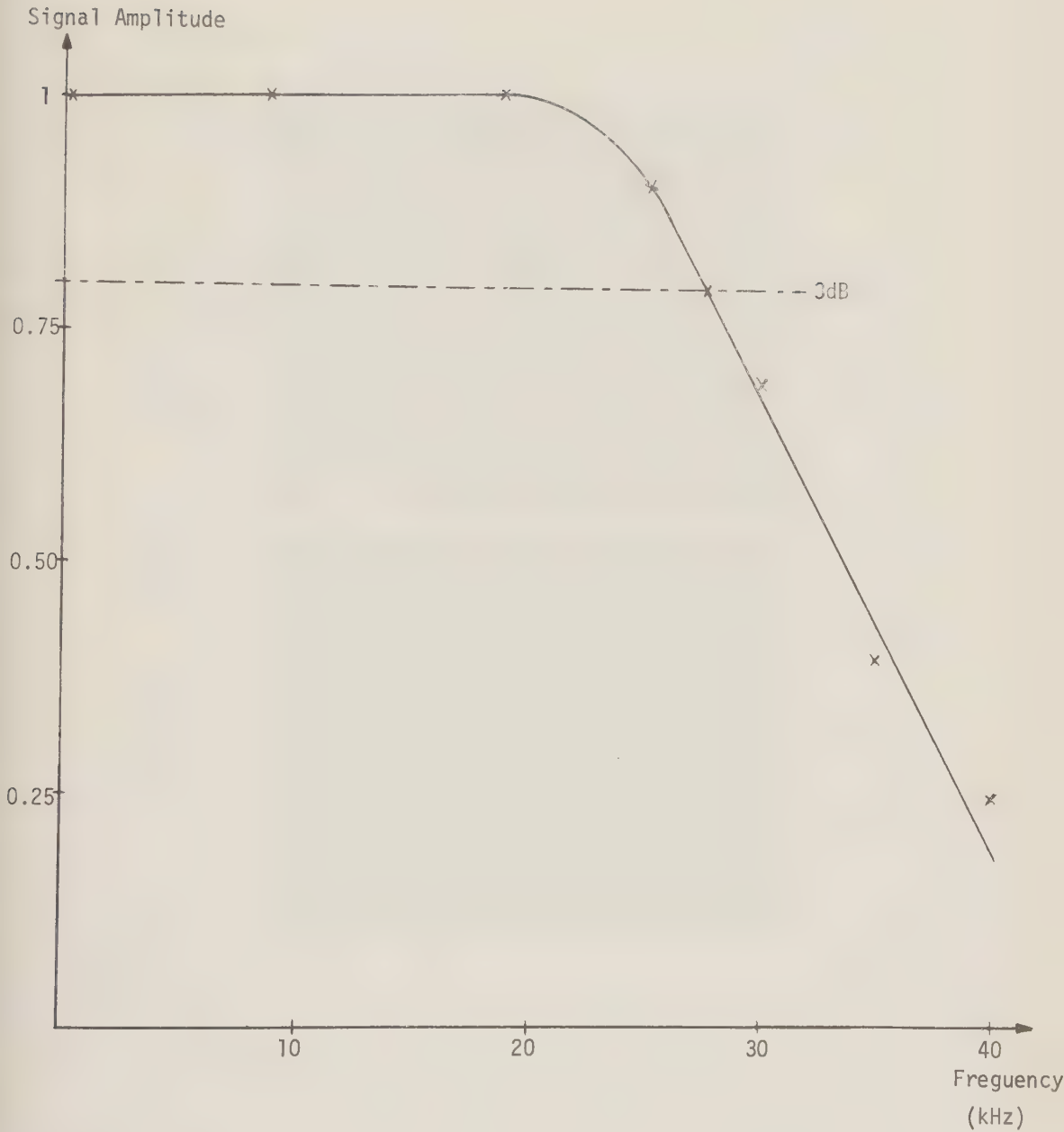


Figure 3.3. Total frequency transfer characteristics of the photodiode/amplifier combination and the following amplifier stages. The -3 dB point is at 28 kHz.

4 ADDITIONAL SIGNAL PROCESSING

4.1 General

This chapter presents the electronic circuitry for additional signal processing of the analog signal as well as its properties. The signal is processed following the final amplifier in Figure 2.9, and thereafter fed directly to the A/D-converter or to a summation amplifier.

In order to evaluate the effects of processing on a digitized image the image is plotted using the Color Jet Plotter. However, for this the signal has to be passed through a pseudo-gray scale algorithm which converts it into a format compatible with the Color Jet Plotter. This conversion algorithm is described elsewhere (Nilsson and Nygren 1981) and is not changed during the analog signal processing experiments.

4.2 Differentiation and edge enhancement

Edge enhancement of an image along the scan line can be provided by a differentiation of the analog signal. If the differentiated signal is added to the original signal, all transitions in the signal are exaggerated (cf. Figure 4.1).

The electronic circuitry used to perform the differentiation is shown in Figure 4.2. It is based on a sample-and-hold unit (AD 532K) and a differential amplifier (CA 3140) and yields a staircase approximation of the derivative.

The input signal is sampled at a sampling frequency set by the sample pulse generator (NE 555). Now, if the sampling frequency is much higher than the frequency of the input signal and the sampling time negligible compared with the hold period Δt , the output V_{out} from the differential amplifier is the change in input voltage between sampling intervals, i.e. the derivative dV_{in}/dt of the input signal with respect to time.

The principle of this analog differentiator has been described elsewhere (Nolte 1977 and Holmer 1978). It yields a stable and accurate solution to the analog differentiation problem. The output from the differentiator is added back onto the original in a summation amplifier shown in

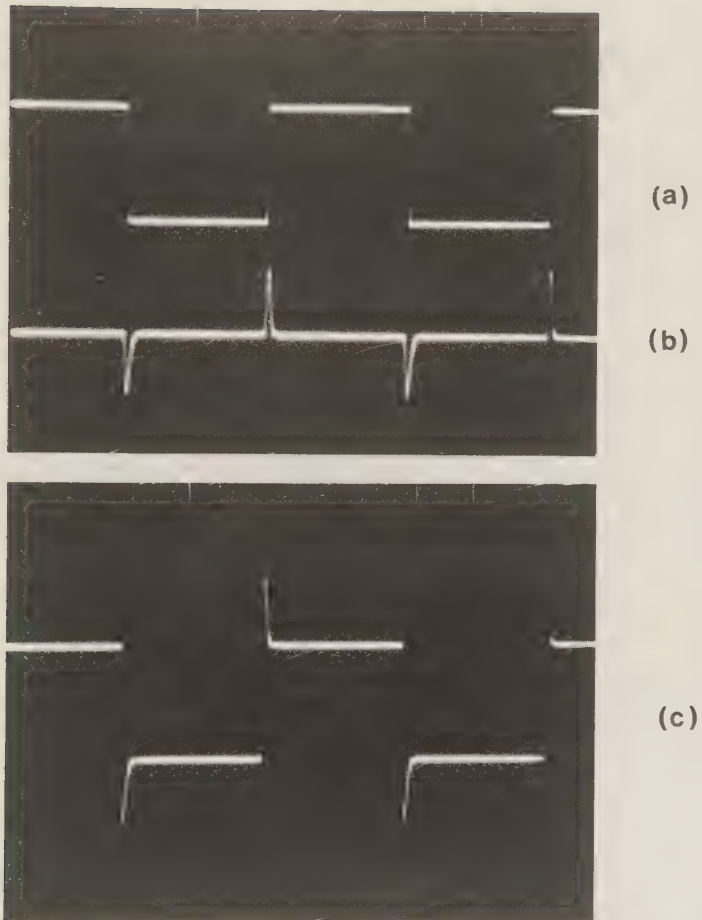


Figure 4.1. Functional description of the differentiation and edge enhancement circuitry:
 (a) Input signal to the differentiation circuitry.
 (b) Signal after passing through a differentiation circuitry.
 (c) Resulting edge-enhanced signal after the addition of the differentiated signal in (b) onto the original signal in (a).
 (Vertical 1 V/div. Horizontal 200 μ s/div.)

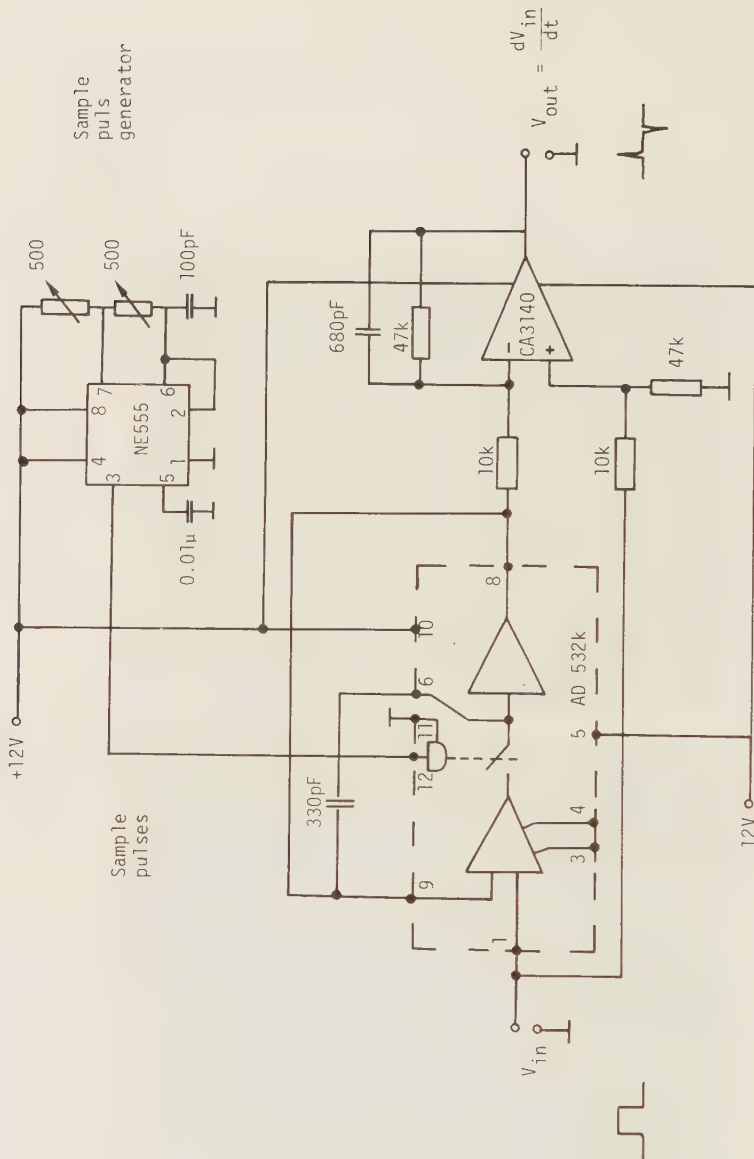


Figure 4.2. A differentiation circuitry based on a sample-and-hold unit (AD532k), a differential amplifier CA3140, and a sample pulse generator NE555).

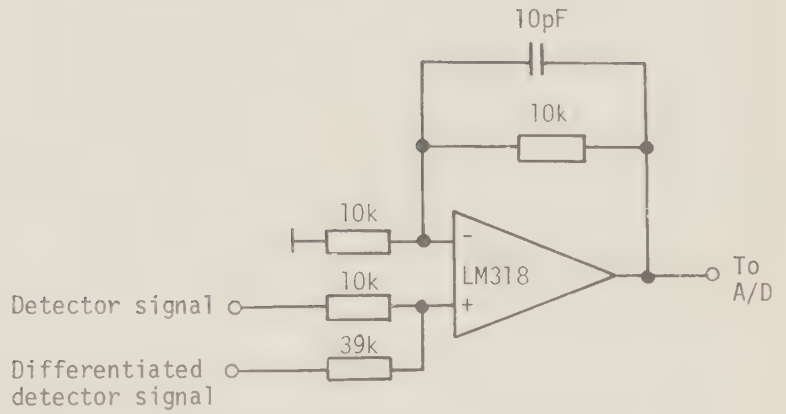


Figure 4.3. Summation amplifier used to add the differentiated signal onto the original detector signal.

Figure 4.3 before the signal is fed to the A/D-converter.

The edge enhancement often results in an image that is subjectively judged to be a "better" image. Figure 4.4 and 4.5 show an example of an image that has been scanned with and without the differentiation circuitry, respectively. The difference is significant especially in the alphanumeric characters in the image. However, the differentiation also introduces unwanted contrast transitions. This is especially visible in the large characters which show a tendency of overshoot at the edges in the scanning direction.

4.3 Contour detector

Contours in an image are lines that surround areas with equal levels of gray or equal color shades. Using a simple contour detector the outlines of such areas can be detected. However, the suggested circuitry has its limitations: Contours perpendicular to a scanning line cannot be detected. Also, only the contours between areas with large contrast differences are sufficiently detected.

The contour detector (cf. Figure 4.6) uses the differentiator, shown in Figure 4.2, and a full-wave rectifier with a single-ended output (Tietze et al. 1978). Now, the differentiating of a square wave pulse representing the signal from a scan line through a white area surrounded by darker areas yields a positive and a negative pulse. After being rectified into two positive pulses, the contour can be detected using single thresholding.

Figure 4.7 shows the result when the contour detector was applied to colored circles. The figure also demonstrates that a contour perpendicular to a scanline is not detected.

4.4 The use of a fourth optional optic fiber

The edge enhancement described in section 4.2 is only functional along a scanline. To enhance detail the other direction as well as the signal from a fourth optional fiber can be used. The aperture of this fiber should be larger ($\approx 3x$) than the normal scanning apertures. This would

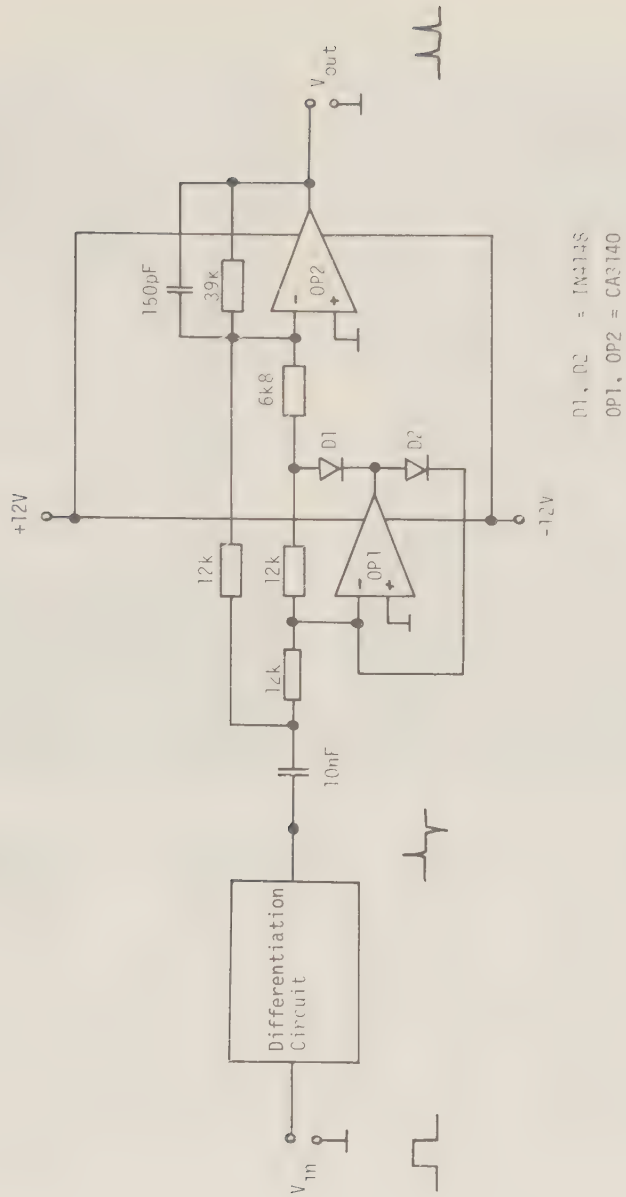
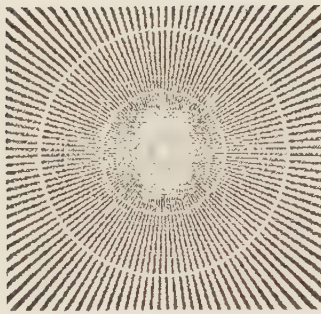


Figure 4.6. A simple contour detector circuitry.

Scanning direction →



NMA MICROFONT QJ K L P Y Z
6 B S I 2 G H 5 D 4 X 7 U 3 W 8 V 9 E
F G P R A D E F G H I J K L M N O P Q R S T U V W X Y Z
P R A D E F G H I J K L M N O P Q R S T U V W X Y Z

A B C D E F G H I J K L M N O P Q R S T U V W
X Y Z a b c d e f g h i j k l m n o p q r s t
u v w x y z 0 1 2 3 4 5 6 7 8 9 O C R - B

A B C D E F G H I J K L M N O P Q R S T U V
W X Y Z a b c d e f g h i j k l m n o p q r
s t u v w x y z 1 2 3 4 5 6 7 8 9 0 P I C A

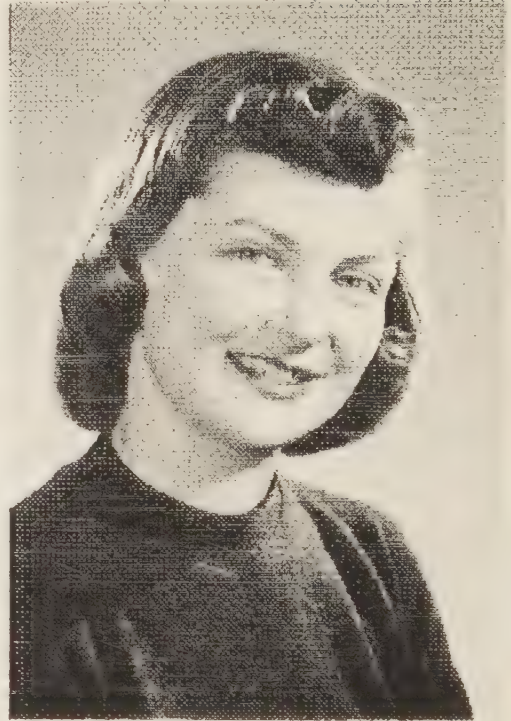
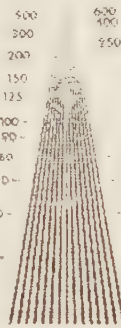
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 Elite

1234567890 Spartan Medium 8 pt

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 Spartan Medium 8 pt

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 Spartan Medium 10 pt

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 Spartan Medium 12 pt



IEEE Std 167A-1980 FACSIMILE TEST CHART

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Figure 4.4. Image scanned with the use of an edge enhancement circuitry.



Figure 4.5. Image scanned without the use of an edge enhancement circuitry.

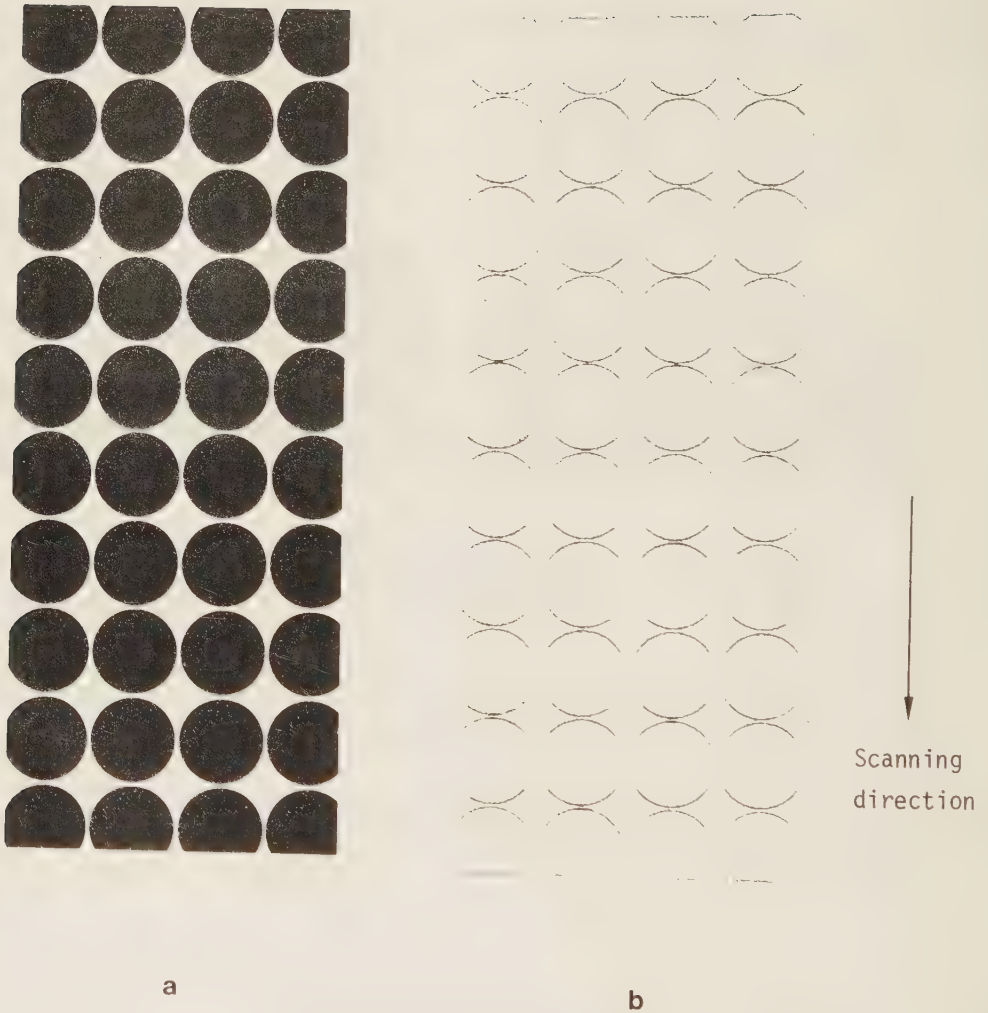


Figure 4.7. An example of the result from the use of the simple contour detector.
(a) original
(b) detected and plotted contours.

then represent the low spatial frequency content in the image. Now, if this signal was subtracted from the normal signal, the resulting signal would represent only the high spatial frequency (fine details) contents of the normal signal. The low frequencies appear equally in both signals and are therefore canceled out. High spatial frequencies are absent from the large aperture signal so they appear in the output at full strength. The output is therefore a record of fine details only, and adding this signal to the normal signal will result in an improvement in fine detail and edge sharpness.

The subtraction of the normal from the large aperture signals may not be implemented in the analog section of the scanner-electronic circuitry, due to the phase shift introduced by the design of the fiber optic apertures. However, it may easily be performed digitally after the A/D-conversion.

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